this feature entirely. The spores of *L. echinosporum* are uniformly dusky in color and covered with irregularly distributed spines which may reach 1.0 μ in length, while in *L. sauteri* the spores are dark violet brown and distinctly lighter on one side, and regularly and densely spinulose, the spines attaining only 0.5 μ in length.

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PERENNATION IN ASTRAGALUS LENTIGINOSUS AND TRIDENS PULCHELLUS IN RELATION TO RAINFALL

Janice C. Beatley

In late winter-early spring (March 15–April 12) of 1965, at a season when precipitation is not predictable, rains of extraordinary frequency and magnitude fell over most parts of south-central Nevada. Rainfall during this period on the Nevada Test Site, Nye Co., was from 2.5 to more than 5 inches at elevations below 5,000 feet, where the communities and flora belong to the Mojave Desert (Beatley, 1969). Late autumn rains the same year were even more extraordinary, and for the 1965 calendar year precipitation totalled 8 to more than 15 inches over the Test Site, with many areas receiving in excess of 10 inches.

A number of biological phenomena following the spring rains, and in the 1966 spring season following the autumn rains, were as exceptional as the rainfall which preceded them. Among these was the appearance in certain areas of conspicuous numbers of seedlings of *Astragalus lentiginosus* Dougl. var. *fremontii* (Gray) Wats. (Leguminosae) and *Tridens pulchellus* (HBK.) Hitchc. (Gramineae) in the spring of 1965, and spectacular flowering populations of the *Astragalus* in the spring of 1966. On permanent study sites located in these areas, year-round environmental measurements and plant data collections in the spring of each year enabled a history of the populations to be quantitatively documented in relation to certain environmental variables.

It is the objective of this report to record the fate of the *Astragalus* seedlings on five sites, and *Tridens* on one site, as a contribution to understanding of the annual-biennial-perennial habit in these, and perhaps other desert species, in relation to precipitation.

Methods

Four of the sites (Plots 16, 17, 66 and 67) were located on the upper bajada of eastern Jackass Flats, a major drainage basin in the southwestern part of the Test Site and at the northern edge of the Mojave Desert. Vegetation was *Larrea-Lycium andersonii-Grayia,* which characterizes the high Mojave Desert vegetation of the region (Beatley, 1969). Soils were predominantly sand and essentially without desert pavement. The sites had an altitudinal range of around 500 feet. Plot 16 was about three miles downslope from Plots 66 and 67, with Plot 17 about half-way between. Plots 66 and 67 were at the divide between Jackass Flats and Frenchman Flat on the undisturbed remnant of a townsite (Wahmonie) laid out in the 1920's; the former was in undisturbed shrub vegetation, and on the latter, in an adjacent clearing for a street of the townsite, there were occasional scattered shrubs of the same species.

On a fifth site (Plot 42), in Mid Valley to the north of Jackass Flats, the *Coleogyne* shrub cover had been destroyed by fire in 1959, and the site was essentially without shrub vegetation during the period of this study. Elevation was over 400 feet higher than that of the Wahmonie sites, and nearly 1000 feet higher than the lowest of the Jackass Flats plots. Desert pavement of the soil surface was in a disturbed condition.

The sixth site (Plot 36) was on the bajada below the Ranger Mountains in southeastern Frenchman Flat, where the vegetation was *Larrea-Atriplex-Lycium shockleyi,* and the well developed desert pavement was typical of that below limestone mountain ranges of the region.

In May 1965, seedlings of *Astragalus* were counted in 50 0.1 m^2 quadrats, and the number/m^2 calculated. Data for *Astragalus* or *Tridens* plants intercepting 11 permanent parallel transect lines, 100 feet long × inch wide and 10 feet apart, were recorded in late May or early June of consecutive years. For each intercepting plant were recorded: 1, the locations of the beginning and ending intercept (to tenths of feet) along each of the 100-foot lines; 2, height, measured to the nearest inch; 3, whether living or dead; and 4, if living, whether flowering, fruiting, or vegetative only. From interception values for the total 1,100 feet of transect percentage cover of the soil surface was calculated for the species.

Rainfall was recorded year-round on each site, using an 8-inch funnel feeding into a two-liter bottle buried below the soil surface. Bottles were emptied weekly, and the measured milliliters converted to inches of precipitation.

TABLE 1. NUMBER OF PLANTS OF ASTRAGALUS LENTIGINOSUS var. FREMONTII INTERCEPTING 1,100 FEET OF LINE (MAY–JUNE), PERCENTAGE COVER, AND PRECIPITATION ON FIVE SITES IN EASTERN JACKASS FLATS AND NORTHERN MID VALLEY, NEVADA TEST SITE, NYE CO., NEVADA (3,800–4,750 feet elevation). 1965–1967.

	Jackass Flats								Mid Valley	
	Plot 16 (3800 ft.)		Plot 17 (465 ft.)		Plot 66 (4330 ft.)		Plot 67 (4325 ft.)		Plot 42 (4750 ft.)	
	1966	1967	1966	1967	1966	1967	1966	1967	1966	1967
Number of plants	236	112	253	153	278	135	236	131	123	136
% living	100.0	0.9	100.0	4.6	100.0	34.8	100.0	41.2	100.0	95.6
% apparently dead	0.0	99.1	0.0	95.4	0.0	65.2	0.0	58.8	0.0	4.4
% flowering/fruiting	100.0	0.0	99.7	2.0	100.0	34.8	100.0	38.9	96.7	95.6
%vegetative only	0.0	0.9	0.3	2.6	0.0	0.0	0.0	2.3	3.3	0.0
Percentage cover	12.0	3.3	11.1	4.7	13.4	5.4	10.3	4.0	6.0	10.4
Precipitation (inches										
Mar.–Apr. 1965 (germination)	2.64		3.25		3.99		4.02		4.04	
May–Oct. 1965 (seedling stage)	1.13		1.06		1.70		1.90		2.78	
Nov. 1965–May 1966 (seeding through flowering/fruiting	5.28		5.45		7.31		7.26		10.36*	
June 1966–May 1967	4.38		4.96		5.63		6.00		8.39**	

* Incomplete; rain gauge overflowed three times.
** Incomplete; rain gauge overflowed once.

Astragalus lentiginosus

Astragalus lentiginosus var. *fremontii* is the common *Astragalus* of the region, where it is usually associated with sandy soils derived from volcanic rocks. In extreme western Jackass Flats, at 3,000-3,300 feet elevation, it is entirely replaced by var. *variabilis* Barneby on deep sands of the bajada below the volcanic Calico Hills. Where soils are derived from limestones and dolomites, the common perennial *Astragalus* is *A. tidestromii* (Rydb.) Clokey.

Seedlings of var. *fremontii* were conspicuous, though scattered, and rather uniformly spaced in the spring of 1965; density was 3–7/m^2 on the five sites under consideration. On all of the plots there was an occasional plant that was not a seedling, but none intercepted the lines at time of the 1965 spring data collections. Apparently all, or nearly all, of the seedlings survived the relatively dry summer and autumn, and following the heavy late autumn rains grew uniformly and rapidly, especially during late winter. By mid-April 1966 nearly all plants were flowering profusely, and by early May were in abundant fruit; plants were commonly a foot or more in diameter, and averaged 7–8 inches high. Over several square miles of eastern Jackass Flats and the larger "burn" of northern Mid Valley, flowering and fruiting populations were the highly colorful landscape feature noted by Barneby (1964) to be characteristic of this variety of *A. lentiginosus*.

In Table 1 are the quantitative data for the populations on each of the five sites, for the 1966 and following spring season. It is apparent from the data that numbers (and size) of plants, and total cover of the soil surface in 1966 were remarkably similar on the Jackass Flats plots. The Mid Valley population was about half the size of the populations in Jackass Flats.

Percentage survival of individuals from 1966 to 1967 in Jackass Flats was in a gradient upslope, and was directly correlated with a precipitation gradient from the lower to the higher elevations. Essentially none survived at the lowest elevation, where there was the least rainfall during all periods. Nearly all survived on the Mid Valley site, at the highest elevation and where rainfall was consistently the greatest from time of germination (and plants in 1967 were commonly two feet or more in diameter). There were somewhat fewer and smaller plants (average 6.6 inches high) in 1966 on the disturbed Plot 67, as compared with the undisturbed Plot 66 (average height 7.8 inches), but the percentage surviving until the next year was somewhat higher on the disturbed site.

The large majority of plants, which germinated in the spring of one season and flowered and fruited the next spring season, and also died the second season, were distinctly biennials; the annual, biennial, and short-lived perennial habit are all ascribed to this variety of *A. lentiginosus* by Barneby (1964). Whether populations or individual plants are biennial or perennial appears from the data to be under the control of soil moisture. The large flowering populations, which appear in the spring on the basin floors of southern Nevada and then vanish for a period of years, apparently are associated with the occurrence the year before of an exceptionally heavy rain, at a time when temperatures were not limiting to germination, and most of the plants were destined from time of germination to be biennials; the number surviving on a given site until the next season is related to the local (and probably micro-variations in) soil moisture regimes. The predominantly perennial populations are those of the higher elevations (4,500-7,500 feet on the Test Site), where there is more frequent and greater rainfall, and greater precipitation effectiveness at the lower prevailing temperatures; even these are usually short-lived, though occasional plants may persist for several years.

It is possible that the rain "triggering" mass germination may also be autumn precipitation, when at least one heavy rain is predictable in this region. Mass germination of this species in the autumn, however, has not been observed at the Test Site, although occasional seedlings commonly occur with the winter annual seedlings after autumn germination. In those flowering the next spring but not surviving to the following year, the life cycle is identical to that of the winter annuals.

Variety *variabilis,* the representative of the species in western Jackass Flats, also apparently germinated following the early spring rains of 1965, but flowered and fruited into mid-summer of the same season, and died during the summer. Perennial plants are scattered in this area, but the largest flowering populations, at least in this case, exhibited an annual growth habit. The variety is described by Barneby (1964) as a perennial of short duration or monocarpic.

Tridens pulchellus

This low, tufted perennial grass, of usually calcareous soils, germinated in large numbers in Frenchman Flat following the 1965 spring rains. In Table 2 are the data for this species on one site for four years along the same 1,100 feet of transect. The seedlings matured, though most of the plants at maturity were less than an inch in diameter, and flowered and fruited abundantly through the late spring of 1965. In the spring of 1966, three-fourths of the plants yet present were dead; apparently 15–20 percent of the 1965 plants survived as perennials through 1966 and 1967. In the 1965 population, around 80 percent behaved as annuals, with a life cycle of several weeks only.

On another site (Plot 33, on the east slope of Frenchman Flat), there were 427 plants in 1967 along the 1,100 feet of transect (where there had been only 13 plants in 1966). The plants germinated following a mid-September rain, 1966, which was locally 1.5 inches on the east slope of Frenchman Flat, and only 0.5 inch or less on Plot 36 and elsewhere on the Test Site. Seeds of this species, therefore, may germinate either in early spring or early autumn. Data were not collected again in 1968,

TABLE 2. NUMBER OF PLANTS OF TRIDENS PULCHELLUS INTERCEPTING 1,100 FEET OF LINE, PERCENT COVER, AND PRECIPITATION, PLOT 36, SOUTHEASTERN FRENCHMAN FLAT, NEVADA TEST SITE, NYE CO., NEVADA (3,085 feet elevation). 1964–1967.

	1964	1965	1966	1967
Number of plants	28	218	125	42
% apparently dead	....	0.0	74.4	0.0
% flowering/fruiting	....	99.1	25.6	81.0
Percentage cover	0.5	2.3	1.4	0.7
Precipitation (inches)				
Mar.–June 1965 (germination through flowering/fruiting)				2.64
July 1965–June 1966				6.64
July 1966–June 1967				5.65

but observation indicated that living plants were rare in the spring of 1968 here and elsewhere on this slope of Frenchman Flat, and for the most part the plants had exhibited a winter annual growth regime.

DISCUSSION

In *Astragalus lentiginosus* and *Tidens pulchellus* it appears the large and importantly reproducing populations in the northern Mojave Desert are biennials or annuals, which germinate following unusually heavy rainfall in the spring or autumn. Only a limited number successfully perennate where precipitation is irregular and variable from season to season. In these environments, those that do become perennial plants flower and fruit during the years between large germinations and give continuity to the presence of the species in the community (of potential significance especially to any dependent consumers in the community). The large perennial populations of *Astragalus* are confined to the higher valley floors and mountains, where there is relative constancy of precipitation above a minimum necessary for the perennial habit. *Tridens* does not occur at the higher elevations in this region, and the perennial populations are those which survive the vagaries of precipitation at the lower elevations.

A potential in higher-elevation perennials for the biennial or annual life cycle at lower elevations could be expected to enable such species to occur over a greater altitudinal range, and hence belong to a greater diversity of plant communities in desert regions, if variables other than rainfall are not limiting at the lower elevations. *Astragalus lentiginosus* var. *fremontii,* in fact, is nearly unique in the herbaceous perennial flora of the Test Site region for its altitudinal range from the lowest to the highest elevations (3,000–7,500 feet), and its occurrence to a greater or lesser degree in nearly all kinds of plant communities, except where soils are highly calcareous. The diversity of communities in which it occurs—from *Larrea – Franseria* to *Artemisia – Pinyon – Juniper* — is matched only by that of *Oryzopsis hymenoides* (R. & S.) Ricker.

The facultative life cycle may characterize a number of other desert herbaceous species usually considered perennial, but which perhaps may in fact flourish intermittently as biennials or annuals during periods following extremes in amount or timing of rainfall. Other perennials in the Test Site flora suspect of having a facultative life cycle are especially the species of *Sphaeralcea, Mirabilis pudica* Barneby, and *Eriogonum inflatum* T. & F., in which large and conscpicuous populations one year are often absent the following season.

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REVIEWS

Principles and Methods of Plant Biosystematics. By Otto T. Solbrig. xii + 226 pp. MacMillan Company, New York. 1970. $9.95.

Solbrig states that his objective has been "to present the theoretical and technical aspects of systematics that are not adequately covered in most of the presently available text-books." Within his self-imposed limits and the limitations of space (possibly imposed by the publisher) he has succeeded remarkably well. As reflected in the title and the quoted excerpt from the preface, the book provides a synopis of current principles and methods used by practicing biosystematists. The book is in two parts. The first summarizes the current rationale behind biosystematic research; the second briefly reviews various "modern" data-gathering techniques employed by biosystematists. The latter section is well suited to development of a series of laboratory exercises to complement the discussions in the former section.

Organization of material, format, illustrations, etc. are very good and the breadth of treatment of particular topics is generally uniform and adequate for elementary students. For advanced classes the discussions form a sound base from which more thorough analyses of particular principles or methods may be developed. The following list of chapter headings indicates the scope of the text: Part I—Introduction and Historical Background, Synthetic Theory of Evolution, Patterns of Phenetic Variability, Breeding Systems, Speciation, Hybridization, and The Species Problem and Classification; Part II—Genetics, Cytology, Chemistry, Mathematics and Statistics, and Conclusion.

Most of the discussions of theoretical points are clear, concise, and well supported through reference to published work. There are, however, several distressing syntactical monstrosities which should never have reached the printed page.